Observing the Planets

A Cassini Science Investigation

Purpose

Get practice at making regular observations of a natural phenomenon and record appropriate data. Understand the effect of Earth's orbital motion on objects in the sky and the apparent motion of outer planets.

Keywords: rise, set, prograde, retrograde, retrograde loop, constellation, star, planet

Materials

- Simple planet orbit chart (included in this activity)
- Star chart (included in this activity)
- Pencil
- Straightedge
- Clipboard (or other solid surface for writing on without a desk)

Procedure

Over the course of several months, students should make weekly (or more frequent) observations of the rise time of available planets and bright stars in the night sky. Eventually, the initially observed objects will be rising in daylight; other objects can be chosen for additional work or conclusions can be drawn based on the observation set already completed.

In addition to noting rise times, students should carefully sketch on a star chart the position of the planet(s) being observed. These positions will be connected and eventually compared to the classroom planetary motion activities described below, using the simple planet orbit chart (“Planet Chart”).

Some variations on the observation procedure should be mentioned here. If it is more convenient to observe setting times for planets and stars, the results will be the same, in that rise and set times occur four minutes earlier (for stars) each day. Observations will have to be made with a precision of about one second for the effect of a planet's motion on its rise/set time to be determined (and that amount will be variable over the course of the planet's period of visibility in the night sky). The Moon can be used as a surrogate planet, instead, with some loss of apparent phenomena. Its daily change in rise time is on the order of tens of minutes (variable, depending on time of "month" and season); time measurement precision, as for star measurements, should be one minute or less. Newspapers often give moon rise/set times for a fixed, nearby geographical point (that will almost certainly be different from where students will observe).

A distant horizon is not a requirement for the observations. The roof of a house, the top of a skyscraper, or the highest branch of a tree can be used as a comparison point. The selected "horizon" can be well above horizontal, as long as the observer's position and the "horizon" are fixed at the same place for each observation.

Students can plot the star's time of rise/set collected daily over a few weeks' time. The slope of the line will approximate 4 minutes per day. Careful measurements of different stars made over a few weeks during each season will show small variations from the 4 minute/day value. These variations are due to the ellipticity of Earth's orbit around the Sun.

The changing time of a star's rise or set can be illustrated in the classroom with the STARRISE chart. Each student can pick any background star on the sheet. Starting on the right end of the diameter crossing Earth's orbit (actually, any of the radii can be used), students should draw a line from the orbit at that point to the selected star. Then the student should draw a line parallel to this original line of sight by measurement or by geometric construction such that the new line passes through the intersection of the next radius and the orbit circle, counterclockwise. Students should then a draw line from the second intersection point to the original selected star. They should immediately note that from the new position, the angle between the star and the old line of sight changes.

Observing and timing the passage of the Sun, as well as stars, can generate a more elaborate classroom and home set of observations. See Edberg, S. J. "Length of the Day," *Practical Uses of Math and Science*, an on-line refereed journal at http://pumas.jpl.nasa.gov, accepted 1997 October 30. The specific URL is

http://pumas.jpl.nasa.gov/cgi-bin/layout.pl?examples:EX00000011-W:inv/examples/07_31_97_1.lbl

The simplified planet orbit chart (“Planet Chart”) is used to illustrate the motions of the planet that have been (or will be) observed in the sky. The Sun is at the center of the circle. The large circle represents Earth's orbit. An outer planet, *without its orbital motion*, is represented by the dot.

Starting on the right end of the diameter crossing Earth's orbit, students should draw a line from the orbit at that point through the planet to the background stars. Students should then continue drawing lines, one step at a time, in a counterclockwise direction (as if an observer were looking down on the solar system from high above the north pole). Each time step is approximately 22.5 days; this is not a magic number, just convenient.

Students should notice how the planet appears to slow down and then go backwards against the background stars, and then slow down and resume its motion. Ask them how this result would be different if the planet itself were moving. (Answer: The extent of the backward motion would be increased. Things get much more interesting if one assumes that the outer planet orbits in the direction opposite of Earth's motion or if it is inclined to the plane of Earth's orbit, or if Earth or the planet have elliptical instead of circular orbits. This can get challenging fast.)

They can even demonstrate the effect of simple planetary motion by repeating this lesson, adding a planet dot on each side of the original dot (about 1 cm left and right; “Real

Motion"). Draw a set of lines from the first three positions on the orbit through the right dot, a set of lines from the next three orbital positions through the middle dot, and the set of lines through the left dot.

The planets work the same way, but of course their motions are smooth and continuous. A continuous set of observations over several months will show the forward-backward-forward motion of the planet against the background stars. This prograde-retrograde-prograde motion is often manifested as a loop or Z among the background stars since the planes of Earth's orbit and other planets' orbits differ slightly.

For the 2000-2001 School Year

During Cassini's science flyby of Jupiter over the period Autumn 2000 through Winter 2001, observers on Earth can see Jupiter in the sky following the Seven Sisters (Pleiades) and above Orion, the large, familiar winter constellation with three bright stars marking his belt. Jupiter will be the brightest object in that area of the sky, looking like a brilliant white star to the unaided eye. To Jupiter's right, slightly fainter, gold-colored Saturn will be leading it during their nightly swing across the sky from east to west.

Over the course of the autumn and winter, Jupiter will rise earlier and earlier due to Earth's orbital motion around the Sun. Early in autumn, Jupiter will just be on the eastern horizon around 9:00 p.m. By late autumn, observers will find it is visible in the east as soon as the sky is dark. In December at 9:00 p.m., Jupiter and Saturn will be very high above the southern horizon, with Orion trailing to their lower left. By 12:00 midnight during December, the planets will have moved to a position high in the western sky. By late winter, the planets will be high in the west just after dark.

The Moon will be close to Jupiter and Saturn on the following nights, making the planets easier to identify. Have the students observe the Moon on these dates plus and minus one day to get a feel for the Moon's monthly motion.

Dates when the Moon is close to Jupiter & Saturn:

16 October 2000
12 November 2000
9, 10 December 2000
6 January 2001
2, 3 February 2001
2 March 2001
29 March 2001

Extension

While neither the Cassini nor Galileo spacecraft (in orbit around Jupiter) can be seen with telescopes from Earth (in fact, the spacecraft can't even see each other), an earthbound observer with binoculars will be able to see Jupiter's four, large satellites. Over the course of one or more nights, their orbital minuets can be tracked. On some nights, as few as two moons may be visible. In order outward, the moons are Io, Europa, Ganymede, and Callisto. Their orbital periods range from less than two days to more than 16 days.

Observers with small telescopes can see the movements of Jupiter's moons and will also be able to see some of the dark belts and bright zones marking Jupiter's cloud tops. Small telescopes will also show a dark band across Saturn, Saturn's rings, and its largest moon, Titan. Titan is comparable in size to Jupiter's largest moon, Ganymede, but it is almost twice as far away from Earth and much more mysterious.

1. Sketch the positions of the moons relative to Jupiter. By making nightly drawings over a period of a few weeks it is possible to sort out which moons are which, based on how frequently they circle Jupiter and their maximum apparent distance from the planet. Students can pretend each is Galileo in 1609 seeing the moons for the first time. How far from the planet does each one get? How fast does each go from side to side and back? Do you see any color differences between them? Use a telescope and sketch Titan's motion around Saturn. How long does it take to make a revolution around Saturn?

2. Compare the colors of Jupiter and Saturn to the colors of the brightest stars in Taurus and Orion. Reddish stars (actually salmon-colored) have temperatures of 3,000°-4,000°Celcius and bluish stars have temperatures exceeding 10,000°Celcius Jupiter's naked-eye color matches the Sun's. At what temperature would you conclude the Sun is?

Star Rise

Background stars.

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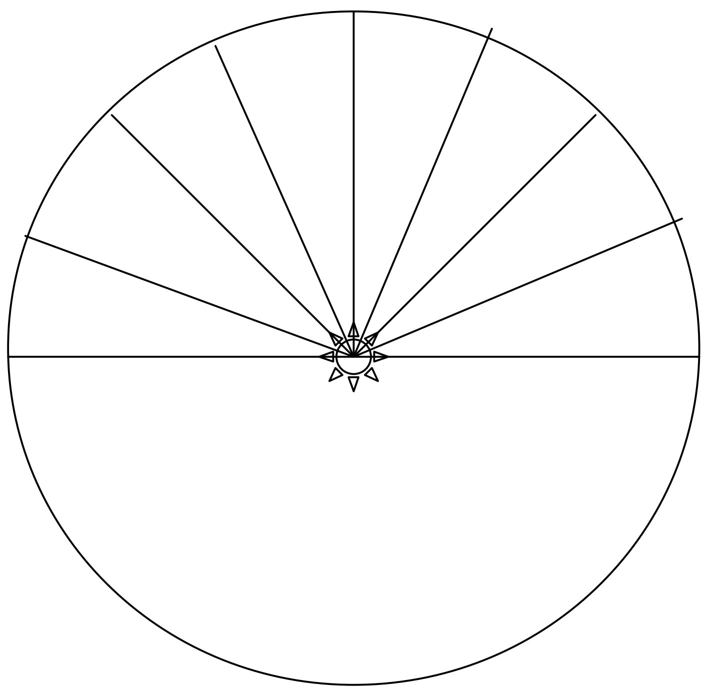
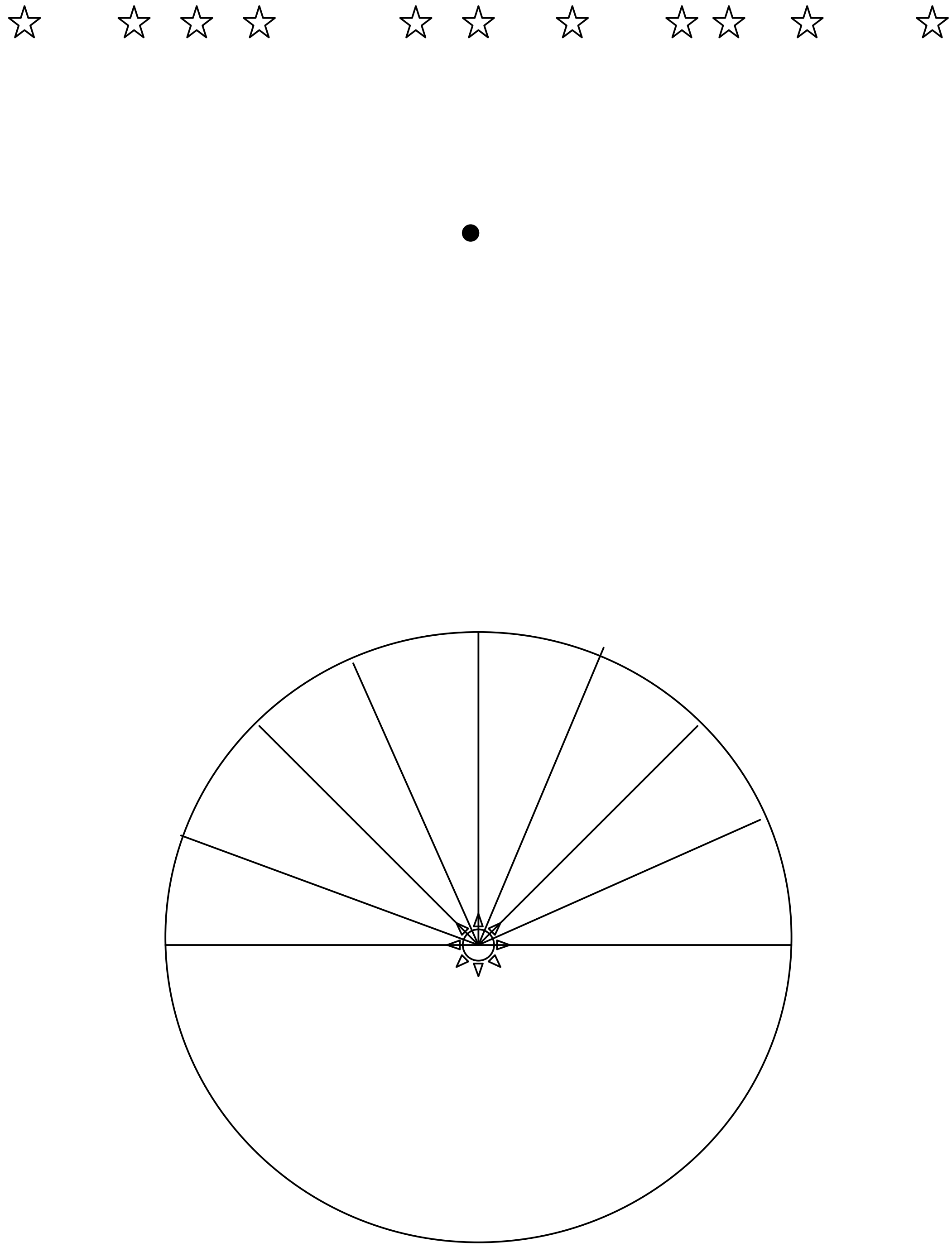


NASA/Jet Propulsion Laboratory
Available to download from http://www.jpl.nasa.gov/jupiterflyby

Planet Chart

Background stars.

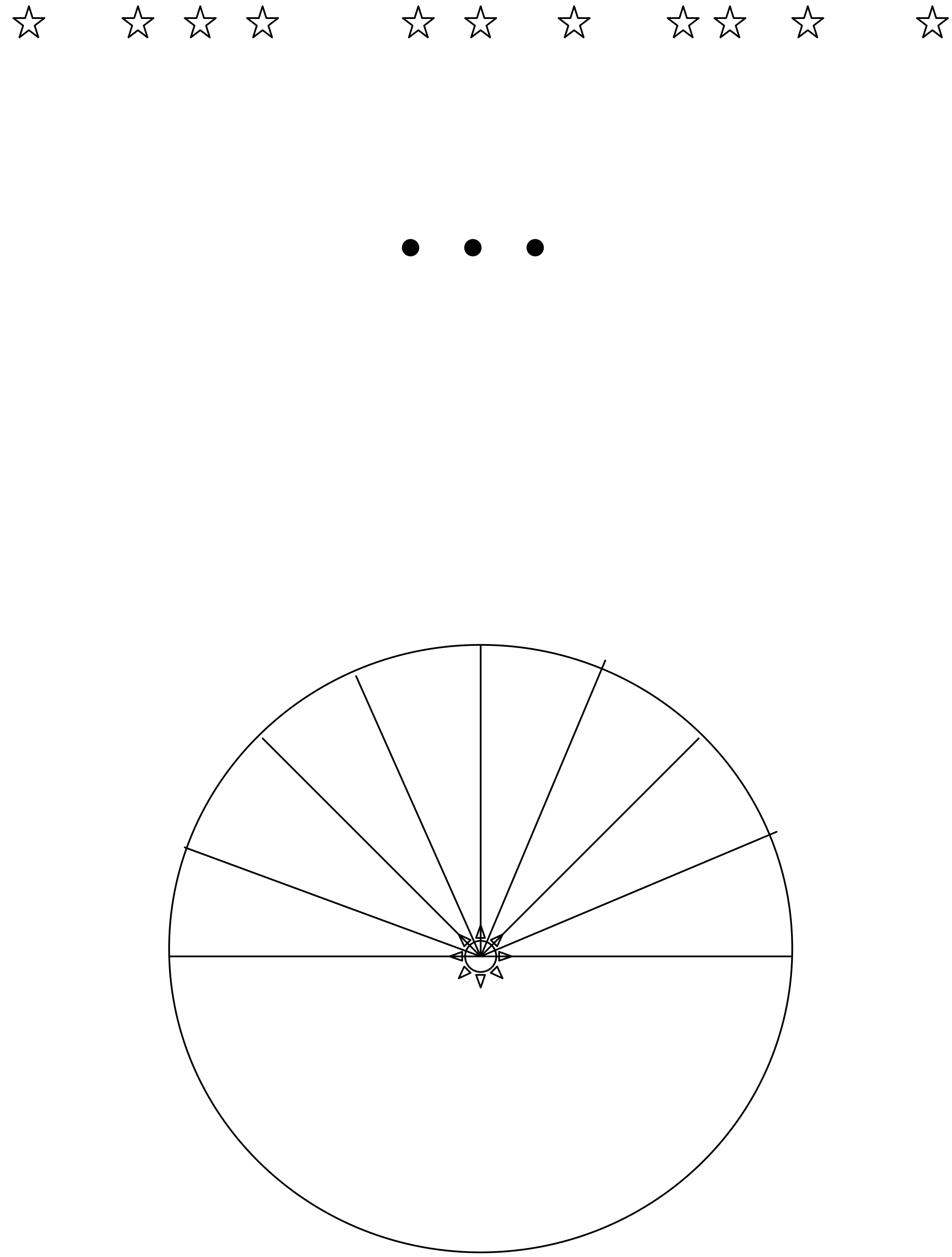


Not to scale.

NASA/Jet Propulsion Laboratory
Available to download from http://www.jpl.nasa.gov/jupiterflyby

Real Motion

Background stars.



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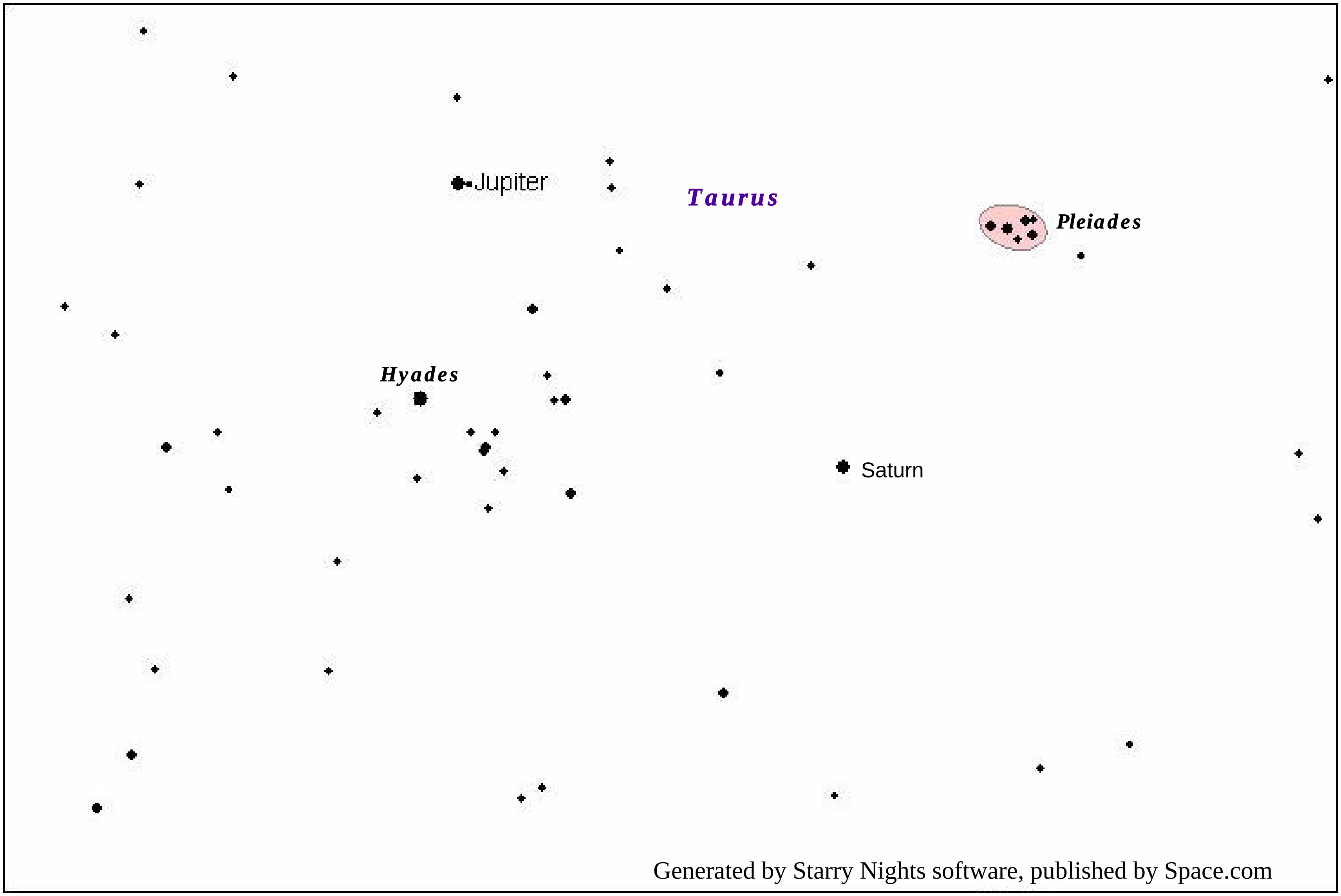
Jupiter & Saturn in the Night Sky - View on 1 October 2000



Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

***Science Standard** 3:* Understands essential ideas about the composition and structure of the universe and the Earth's place in it.
Level 1 (K-2): Knows basic patterns of the Sun and Moon (e.g., the Sun appears every day, and the Moon appears sometimes at night and sometimes during the day; the Sun and Moon appear to move from east to west across the sky; the Moon appears to change shape over the course of a month)
Level 2 (3-5): Knows that the patterns of stars in the sky stay the same, although they appear to slowly move from east to west across the sky nightly, and different stars can be seen in different seasons.
Level 2 (3-5): Knows that planets look like stars, but over time they appear to wander among the constellations
Level 3 (6-8): Knows characteristics and movement patterns of the nine planets in our Solar System (e.g., planets differ in size, composition, and surface features; planets move around the Sun in elliptical orbits; some planets have moons, rings of particles, and other satellites orbiting them)

***Science Standard 12**: Understands motion and the principles that explain it*
Level 1 (K-2): Knows that the position of an object can be described by locating it relative to another object or the background
Level 2 (3-5): Knows that an object's motion can be described by tracing and measuring its position over time

*S**cience Standard 15**: Understands the nature of scientific inquiry*
Level 1 (K-2): Knows that learning can come from careful observations and simple experiments